Appendix C: Interior Columbia Basin Stream Type Chinook Salmon and Steelhead Populations: Habitat Intrinsic Potential Analysis

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Introduction

Interior Columbia River Basin (ICB) salmon and steelhead have evolved to take advantage of a wide diversity of habitats. Climatic, geological, topographic, and landcover patterns have produced a robust evolutionary trajectory in streams flowing through vastly disparate terrestrial environments. This opportunity for uniquely adapted populations has created a challenge for identifying, both qualitatively and quantitatively, intrinsic habitats within large watersheds such as the ICB. Though salmon and steelhead occupy streams flowing through a wide spectrum of upland environments, their freshwater habitat preferences are limited to a comparatively narrow set of hydrological and streambed conditions (Reiser and Bjornn, 1979). However, it is the interaction between apposite flow path structure and adjacent terrestrial geomorphologies that determines intrinsic suitability. Ultimately, site specific stream reach characteristics and salmonid habitat preferences are influenced negatively and positively by both adjacent and out of view landscapes.

The analysis described below is intended to provide a simple and objective overview of the distribution of historical production potential across the tributary habitats used by Interior Columbia basin yearling type Chinook and steelhead populations. The initial iterations of our approach were patterned after an analysis of Puget Sound Chinook habitat potential developed by the Puget Sound Technical Recovery Team. That approach relied on empirically derived relationships between salmon spawner densities and channel characteristics (Montgomery et al., 1999). In the Puget Sound Chinook application, production potential was expressed in terms of spawners per unit reach length and related to a set of physical reach level measures: stream width, stream gradient, valley width and vegetative cover. In combination these factors were related to the relative amount of pool habitat, an important determinant of relative spawning and juvenile density. Similar sets of reach level habitat measures have been used to map relative production potential for coho and steelhead in Oregon coastal watersheds (Nickelson, et al., 1992, Burnett, 2001) and for steelhead in the Willamette River drainage (Steel, 2004).

Methods

We developed a reach level intrinsic potential (IP) analysis for application to stream type Chinook and steelhead spawning reaches assess habitat quality within currently and historically occupied portions of the ICB. This approach has enabled us to formulate a baseline perspective from which we can assess contemporary changes to productivity. Utilizing established relationships between habitat type, stream structure, landscape processes, and spawning use, we built a locally adapted Geographic Information System (GIS) based model incorporating regional spatial data, fisheries surveys, and professional knowledge. The GIS was used for the development, presentation, management and modeling of spatially referenced data. Modeled geomorphological characteristics were assigned to unique categories comprised of gradient, width, and valley confinement, from which additional stream and landform modifiers were incorporated to adjust intrinsic potential. We then evaluated these classes against known distributional densities in order to test modeled habitat quality. Results from these comparisons were used to weight and summarize reach areas for the entire stream network within the ICB based on relative Chinook salmon and steelhead habitat preferences.

We used the following process to develop the historical intrinsic potential analysis for Interior Columbia basin tributary habitats:

1. Fish density vs. habitat characteristics: Reviewed literature and available data sets relating simple measures of habitat characteristics to production potential for salmon and steelhead.

2. GIS data acquisition: Acquired and developed GIS data describing key habitat measures related to salmon and steelhead production potential for ICB ESU populations as determined in step 1.

3. Determining boundaries: Identified and applied criteria for defining the upper and lower boundaries to Chinook salmon and steelhead production within ICB watersheds using natural barrier locations and other habitat factors.

4. Initial classification: Classified stream reaches based on habitat characteristics (stream width, gradient, valley confinement) into categories representing varying levels of relative productivity. These habitat classes where then used to attribute spawning reaches, with respect to modeled salmon and steelhead production potentials, as high, moderate, low, negligible or none.

5. Preliminary validation and updating: Compared results from step 4 against specific measures of relative abundance of spawning adults and provided output to regional fisheries biologists for review. Additional habitat factors (reflected in GIS layers) were incorporated into the IP analysis to improve the correspondence of modeled distributions with empirical data and field observations.

6. Finalizing and applying reach level ratings: Finalized relative spawning potential rating categories as a function of physical habitat characteristics, and generated weighted totals by population and associated sub areas.

Fish Density Data Analysis

Our preliminary efforts focused on identifying published data and reports that related simple measures of habitat characteristics to stream type Chinook salmon and steelhead production. We found that direct measures of life stage specific productivity within particular reach characteristics are rarely available at fine scales or distributed across multiple watersheds. In fact, there is no single dataset with a consistent measure of relative abundance across the full range of environmental conditions found within ICB streams. As a result, we based our investigation on a set of discrete regional data sets. In general, we utilized spawning surveys, habitat studies, and stream transect juvenile sampling data to describe relative densities of stream type Chinook and steelhead in geospatially specific stream reaches.

Juvenile Abundance Transects

Initially, analyses relating densities of juveniles measured at a consistent life stage to habitat characteristics were used to assign relative intrinsic potential ratings and identify important structural elements within stream reaches. Studies generally show that for both yearling and stream type Chinook, juvenile densities are typically highest in relatively low gradient, unconfined stream reaches with well defined pool structure (e.g., Hillman& Miller, 2002, Petrosky & Holubetz, 1988), while steeper gradient relatively confined tributary reaches typically support the highest relative densities of juvenile steelhead (e.g., Slaney et al., 1980, Petrosky & Holubetz, 1988, Burnett, 2001). Steelhead have also been reported to use braided mainstem reaches for spawning and rearing, given appropriate flow, temperature and substrate conditions (e.g., ODFW, 1972).

Idaho Parr Data. Using juvenile transect survey data collected by the Idaho Department of Fish and Game (IDFG), we completed additional analyses comparing juvenile abundance to stream habitat. In the early to mid 1980's, IDFG biologists compiled a baseline data set for evaluating the effectiveness of habitat improvement projects. The data set included both measures of parr densities (Chinook and steelhead/rainbow trout) and habitat measures. The IDFG studies (as concluded (as discussed above) that Chinook parr densities were the highest in low gradient stream sections in relatively wide valleys and that steelhead/rainbow juvenile densities were the highest in steeper gradient, more confined reaches (e.g., Petrosky & Holubetz, 1988). The original analyses focused on data collected in years with relatively high parental escapements to minimize the confounding effect of relatively low seeding (Petrosky and Holubetz, 1988). We used data from naturally seeded areas from that parsed data set for the current analyses. For stream type Chinook (figure 1) and steelhead (figure 2), parr densities were plotted against gradient and stream width within two valley width categories corresponding to B channel and C channel designations (Rosgen, 1985) used in the original study. We found that wider stream reaches known to be used for spawning and rearing by steelhead were not well represented in the Idaho baseline study. A second data set, compiled by the Washington Department of Game for larger rivers in western Washington and Puget Sound, was also analyzed to provide some insight into production relationships in larger systems.

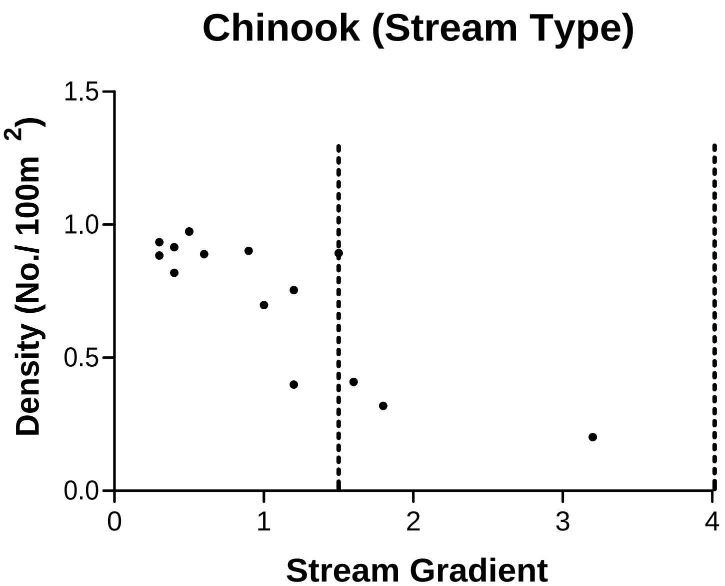

Figure 1. Idaho Spring/Summer Chinook. Juvenile densities vs. stream gradient for naturally seeded baseline monitoring areas in the Salmon and Clearwater River systems. Parsed data set—low seeding years not included (Petrosky and Holubetz, 1988). Dotted lines indicate assigned category boundaries.

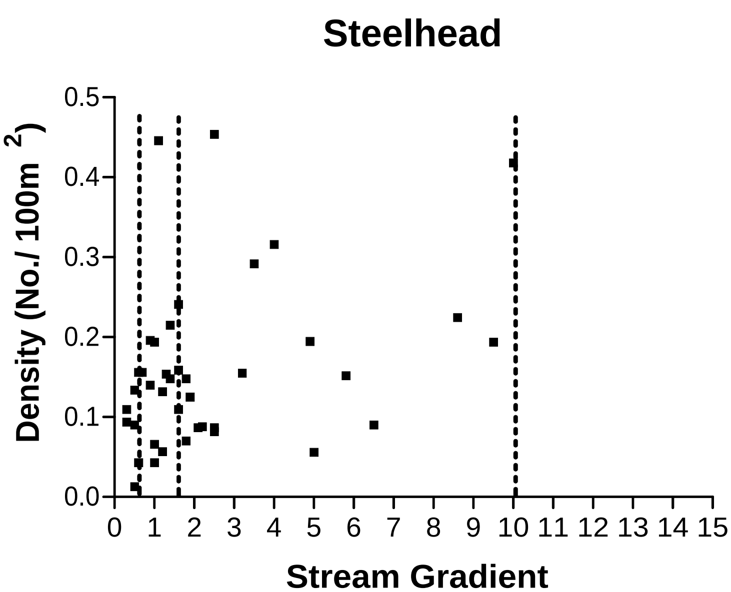

Figure 2. Idaho Steelhead. Juvenile densities vs. stream gradient for naturally seeded baseline monitoring areas in the Salmon and Clearwater River systems. Parsed data set- low seeding years not included (Petrosky and Holubetz, 1988). Dotted lines indicate assigned category boundaries.

The results from these investigations became the foundation for our habitat modeling scheme and helped identify the structural elements that would be required for additional analyses. Specifically, it became quite apparent that accurate measures of stream width, gradient, and valley confinement would be crucial for assessing intrinsic potential within the GIS. Developing models and acquiring data that describe these variables at a reasonable scale became our next task.

GIS Data Acquisition and Modeling

The National Hydrography Dataset (NHD) 1:100,000-scale networked reach model was used as the base stream layer for our intrinsic potential analysis. The NHD's layer contains all hydrographic features, including naturally flowing reaches and anthropogenic constructs such as irrigation canals, ditches, and laterals. Using only natural flow paths from the networked data, we built a linearly referenced stream layer comprised of contiguous 200-meter stream reaches. Segments were *addressed* using a "from", "to", and "id" field by dividing each unique stream into a continuous set of 200-meter tabular entries (stream length / 200 = number of events per stream), from which linear referencing processes were used to geocode address attributes within the hydrography network. This segment length was chosen to facilitate our classification of salmonid barriers, as a 200-meter reach with a 20% gradient has been found to be impassable for upstream migrants (Cramer, 2001; WDNR, 2002). These 200-meter hydrosections have become the basic unit of measurement for all ICTRT intrinsic potential summaries and analyses.

Stream Gradient

Stream gradient has been found to be an important habitat qualifier for salmonid spawning preference, and is determined by the change in vertical distance over reach length. As a flow path characteristic, gradient functions both as an indicator of upstream limit on migration (Cramer, 2001; WDNR, 2002) and as a predictor of habitat quality within accessible reaches (Cramer, 2001; Lunetta *et al*., 1997). Within the GIS, we used linear referencing techniques and zonal statistics to generate elevation values for all 200-meter stream segments. The minimum (downstream-most point) and maximum (upstream-most point) stream elevations were calculated using the USGS's National Elevation Dataset (NED) 10-meter horizontal resolution digital elevation models (DEMs).

Although spatial agreement is relatively high between the NHD's 100k hydrography and the NED, we had to augment standard neighborhood analysis techniques recognizing that even small misalignments can introduce large errors into the gradient calculations. We developed a procedure using Euclidean geometry to assign elevations for each segment in order to resolve the relatively small geographic differences between the DEM flow paths and our NHD derived 200-meter reach segments. Within each stream length, 10 equally spaced positions were linearly referenced to the reach and were given a unique code. We then calculated a contiguous zone for each point and computed a zonal statistical summary comparing the Euclidean output to the DEM. From these data, the minimum value determined for each zone was assumed to be the elevation of the DEM flow path, and therefore assignable to the vector stream layer for computational accuracy. An additional summary was generated for each unique 200-meter stream segment in order to obtain the minimum and maximum value from the previous calculation that used intervening points. Using the measures from this output as the upstream and downstream elevations, we attributed all linear features with their computed gradient.

Channel Bankfull and Wetted Width

Stream widths are an important metric for determining the amount of available habitat and the upstream extent of migrants. In our analysis, we have utilized both bankfull and wetted widths as a means of recognizing spawning time differences between stream type Chinook and steelhead. Because steelhead spawn near the peak of the hydrograph, and conversely, stream type Chinook salmon spawn near its lowest point, it was more accurate to assign different stream dimensions for both species. Therefore, we have applied bankfull width to steelhead and wetted width to stream type Chinook salmon, and all measurements relating to specie specific habitat totals include these adjustments in the calculations.

Stream width is predominantly a function of stream discharge, which can be estimated from a combination of drainage area and precipitation (Leopold *et al.*, 1964; Sumioka *et al*. 1998). Therefore, utilizing discharge as a proxy for stream width, we estimated stream dimensions from watershed size and mean annual precipitation. We used measured widths from field based stream measurements within the Columbia River basin to develop equations for estimating bankfull and wetted width (ODFW, 1999; WDOE, 2004). Upstream drainage area and accumulated average annual precipitation for each width measurement were derived from 60-meter DEMs (resampled from the 10-meter NED) and a 4-km grid of mean annual precipitation (1971-2000) (NCDC, 2004).

We conducted an analysis using linear regression between measured stream width and the accumulated precipitation and basin size metrics. For bankfull width, we applied the appropriate channel measurement within the field data; for wetted width, only measurements taken during August and September were included to accurately represent stream type Chinook salmon spawning times. Both analyses yielded statistically significant relationships between the basin size, precipitation, and stream width values and the resulting regression model was applied to the 200-meter reach data.

Valley Confinement

We estimated mean valley width for each reach by projecting 20 transects across the DEM-defined valley floor in each 200-m segment, and then calculating the mean valley width of the segment. The horizontal extent of the transect (valley width) was determined using flood height calculations from previous studies (Hall, 2007). As with our gradient calculations, we accounted for spatial discrepancies between the NHD 100k streams and the DEM flow path by calculating floodplain width based on the DEM flow path, and then assigning the calculated floodplain width to the 200-meter stream segments for subsequent data analyses.

Specifically, the valley width was calculated by creating a Euclidean based layer whose value was inherited from and spatially centered to the flow path elevation for each transect. Additionally, the flood height value was added to this grid layer, and the resulting calculation was subtracted from the NED. The results in this output grid showed the extent of the floodplain (based on the assigned flood height) where the values were less than or equal to zero. These valley areas were then summarized for all 20 transects independently, from which a mean value was generated and attributed to each 200-meter segment.

Determining Upstream and Downstream Extents

Upstream limits on the potential use of tributary habitat for spawning and rearing by salmon and steelhead were defined in terms of physical barriers, stream gradient, width, and water temperature. Reaches above documented natural obstructions and DEM calculated gradient barriers were excluded as production areas. Stream reaches with gradients above 5% were also excluded as spawning/rearing areas for yearling Chinook salmon populations based on expert opinion and on a review of index reach data sets for ICB streams. Minimum stream widths capable of supporting spawning were estimated based on available width measurements for index reaches with documented redd counts and mapped distributions. Additionally, a water temperature model was used to mark the downstream extent of spring Chinook salmon in Upper Columbia and Lower Snake River populations.

Natural Barriers

Barrier identification was our first data development scheme describing habitat quality, and employed both GIS calculated gradient barriers (representing the 20% limit described previously), and documented features such as falls, cascades, and reaches disconnected by sub-surface flows. We have utilized multiple digital, hardcopy, and field personnel sources to determine where natural obstructions mark the upstream extent of salmon and steelhead habitat. When possible, GIS datasets describing barriers were identified and incorporated into the base layer. In many cases archived report material and expert opinions had to be transferred to digital media and spatially referenced using recorded locations (such as river distance or an identifiable landmark). We have converted all sources of information into a GIS point feature theme and have preserved narratives and source information.

Within our IP analysis, natural barrier identification has been an ongoing process. Some features previously identified as complete barriers have been removed due to inconsistent information (such as salmon or steelhead observations above these locations) and others have been labeled as variably accessible due to significant year to year changes in stream flow, and hence passability. Local review of ICTRT data has provided many new additional barriers, which have been used to update stream accessibility metrics. In all cases, we have identified the 200-meter segments adjacent to complete migration blockages and have attributed all corresponding upstream features as inaccessible habitat.

Stream Width

Stream channel size generally decreases as you move upstream. At some point, stream dimensions constrict to such a point that habitat becomes unusable for salmon and steelhead. For spring Chinook, we used two data sets in order to determine stream size limitations; results from recent USFWS redd mapping efforts in the Middle Fork Salmon River, and Grande Ronde redd count index reaches. For steelhead, we utilized John Day redd count index reaches, O. *mykiss* presence/absence data from ODFW, IDFG parr count transects from the Salmon and Clearwater basins, and suitability maps developed by IDFG (Thurow, 1988). Channel widths calculated for the 200-meter segments used in the IP analysis were spatially joined to each dataset, and mean values were summarized for each unit. In both the spring Chinook and steelhead analyses, we used the 95th percentile low value for bankfull and wetted width to delineate our upstream extent. Use of smaller tributaries for juvenile rearing has been documented (e.g., Nez Perce tribal comment letter), and spawning in smaller tributaries may occur in particular situations. Further discussion of our stream width metrics will follow in the next section.

Water Temperature

The lower reaches of many interior basin tributaries are subject to summer temperatures that are well above levels injurious to salmon and steelhead. Persistent high temperature levels can have a significant impact on the ability of a given reach to sustain both juvenile rearing and adult spawning. Although current thermal regimes within ICB drainages are significantly influenced by human activities, it is likely that some lower reach habitat has always been temperature limited. Unfortunately, there are no temporally or spatially broad datasets describing historical temperature profiles, so any model using contemporary data reflects current habitat degradations. This is important to note, because any modeling exercise which uses current data will have output shaped by modern externalities.

A Streamnet (1999) temperature dataset was used for modeling water temperatures as they relate to environmental characteristics. We adopted the temperature criteria used by Chapman & Chandler (2001) which determined that a weekly mean average temperature (WMAT) exceeding 22 degree C could potentially limit or exclude salmon and steelhead production. Using NCDC mean July temperatures (1971-2000), percent forest cover (calculated from USGS NLCD), and elevation (USGS DEM), we developed a reach specific model that predicts the likelihood of exceeding a WMAT of 22 degree C. In the Streamnet dataset we chose data points that were the least likely to be anthropogenically altered. These included locations directly above or below dams, within irrigation infrastructures, or adjacent to urbanized areas. The final analysis revealed significant relationships between a WMAT of 22 degree C and air temperature, percent forest cover, and elevation. These variables were used to develop a simple screen that either included or excluded 200-meter segments within the 22 degree C zone. This delineation was then used to define the lower extent of spring Chinook salmon spawning potential in Upper Columbia River and Lower Snake River Populations. It should be noted that the initial set of variables used in this analysis do not reflect the effects of groundwater on ameliorating temperatures in mainstem reaches with broad, alluvial flood plains such as those found in the Lower Yakima River.

Reach Level Habitat Potential Ratings

Four different habitat measures were used to define our criteria for estimating reach specific production potential for stream type Chinook and steelhead within ICB habitats. The characteristics selected were; (1) stream width (modeled as bankfull and wetted width), (2) stream gradient (change in elevation over reach length), (3) valley width (relative width of valley compared to bankfull width) and (4) riparian vegetation (as a percent of landcover). We previously discussed how these variables were calculated using a GIS, and will now describe the methods employed for categorizing data.

Stream Width.

We established three stream width categories after considering the range of widths associated with the empirical density data for Interior Columbia streams, the relative distribution of channel widths in areas identified as supporting steelhead spawning in the basin and the categories employed in the Puget Sound analysis. The three categories were 3.6 m(wetted) or 3.8 m(bankfull) to 25 m, 25 - 50 m and >50 m. The rationale for our upstream extent (minimum stream width) was described earlier, and agrees with other observations. For example, streams less than 3 m in bankfull width were at the lower margins sampled in the Idaho baseline study. Also, presence/absence data provided by the Nez Perce Tribal staff indicates that few streams less than 3 m support production for steelhead. WDFW has recommended using a 2 m wetted width as the lower limit for steelhead in western Washington streams. Although most transects within the Idaho parr data were between 3.8 m and 25 m bankfull width, the WDG study included mainstems up to 50 m wide, and this value defines the upper limit of our moderately sized width class. Very little abundance data existed for the largest mainstem rivers (>50 m).

Based on previous analyses, we set lower limits relative to spawning/rearing potential of 3.6 m (wetted width) for Chinook and 3.8 m (bankfull width) for steelhead. Spring Chinook spawn in the late summer and early fall, and summer wetted width is an appropriate measure of stream size relative to this time period. Steelhead spawn in the late spring on the end of the spring freshet, and bankfull width is a more appropriate measure of stream size relative to this period.

Valley Confinement

The Idaho baseline study classified streams as B or C type channels using criteria defined by Rosgen (1985). Using the valley confinement estimates calculated earlier, we defined 200-meter reaches within our IP analysis as C type if valley width exceeded 20 times bankfull width. Values less than 20 times bankfull width were either attributed as confined or unconfined (defined below).

Confined streams with moderate to high gradients are unlikely to exhibit the stream structures necessary to support salmon and steelhead spawning. We incorporated a measure of confinement (as a function of valley to bankfull width) into our IP criteria, and assigned categories to all 200-meter segments. Streams that have a valley to bankfull width ratio less than 4 are defined as confined, and have virtually no opportunity for lateral channel migration and floodplain development (Beechie *et al*., 2006, Hall *et al*., 2007). This means that confined channels lack instream processes which promote the development of suitable spawning substrates. If valley width was less than 4 times bankfull width, a stream segment was attributed as confined and the intrinsic production potential was downgraded by one level.

Gradient

A set of gradient categories was developed based upon the Puget Sound TRT Chinook matrix (e.g., Table 2 in WRIA 18 Draft Summary Report - Puget Sound Chinook Recovery Analysis Team) and the categories used in the Idaho and Washington Game Department studies. For Chinook, most of the observed parr density/stream gradient data pairs fell within the 3 to 25 m stream width category. In general, densities were relatively high at gradients below 1.0 to 1.5 %. Although observations were relatively sparse, densities were low at gradients exceeding 1.5 to 2.0 percent. The frequency of samples exhibiting low pool cover (less than 50%) increased rapidly as gradients exceeded 1.5%.

Steelhead exhibited the reverse pattern with relatively low densities at gradients below 0.5, increasing as gradients rise to approximately 4%. Steelhead parr densities remained relatively high as gradients increased above 4%. We assigned the highest potential rating to gradients between 4% and 7% (an upper limit consistent with expert opinion cited in the draft Lower Columbia/Willamette TRT Viability report). Stream reaches in the 3.8-25 m bankfull width category that had gradients between 7 and 15% were designated with low potential. No spawning potential was assumed if gradients exceeded 15%. Steelhead parr densities at gradients exceeding 1.0 remained at relatively high levels in the widest streams in the sampled areas, but transects located in streams greater than 20 m bankfull width were not well represented.

We used adult steelhead spawning surveys to supplement the parr data analyses in determining relative ratings for streams exceeding 25 m bankfull width. Klickitat River index redd counts (YKFP 2002) and radio tracking results for Yakima Basin steelhead (Hockersmith et al., 1995) were geo-referenced and used to describe width and gradient classes in spawning locations within larger streams. We modified our ratings for the 25-50 meter wide category using the relative ratios generated from these analyses.

Riparian Vegetation

An additional modifier was originally incorporated into the framework based on forest cover as a source of large woody debris (LWD). Using the USGS (2000) National Land Cover Dataset (NLCD), we calculated the percent of forest within buffered 200-meter stream segments, and classified reaches with greater than 90% forest cover as mesic forest. In Puget Sound stream systems (PSTRT 200?), pool structure is affected by the availability of large woody debris (LWD), which can mitigate for the limitations of moderate gradient reaches. Initially, we included the assumption that LWD sources within adjacent riparian areas (classified as mesic forest) would result in increased pool structure in moderate gradient reaches (and would therefore increase suitability). However, analysis of the USFWS Middle Fork adult redd data set did not support increased production potential (redd densities) in forest versus non-forested reaches in moderate gradient or confined reaches. As a result, we dropped this rating category from our analysis.

Initial Rating Assignments

Classes assigned to stream gradient, width (bankfull and wetted), and valley confinement were grouped into habitat categories and given a rating of “high”, “moderate”, “low”, or “none.” These relative ratings were determined from observed life stage specific abundance values within specific habitat classes and applied to the 200-meter stream segments within our IP dataset. Maps from this exercise were distributed to regional biologists for review.

Review and Modification Including Additional Habitat Screens

The results from our habitat suitability classification were analyzed using two methods: solicited reviews from field biologists and comparisons with current spawning survey summaries. Firstly, maps were developed for individual watersheds and distributed to local agencies for review and comment. Feedback from this process then became the basis for developing sediment and stream velocity habitat screens as they relate to intrinsic quality. Secondly, statistical comparisons were made between IP habitat classes and productivity as measured by redd counts. The spring/summer Chinook survey from the Middle Fork Salmon River (USFWS) was used for our IP analysis of stream type Chinook, and WDFW steelhead surveys in the Upper Columbia (2004-06) were used to compare with O. mykiss IP values. Both datasets were important because they included redd surveys of entire streams, making non-occupied reaches significant and comparable to IP modeled categories. Based on these comparisons, some class specific adjustments were made to IP ratings, most notably for adding confinement as a significant feature in steelhead ratings, modification of gradient and width classes, and removal of the mesic forest modifier.

Habitat Screens-Sedimentation

The ability of a particular reach to support salmonid spawning can be significantly affected by sediment conditions within that reach (e.g., Bjornn and Reiser, 1991). Relatively low gradient stream reaches meandering through wide valleys can be deposition areas for fine sediments, especially if the surrounding soil types are highly erosive and fine grained. We used available GIS layers summarizing soil characteristics to assign relative indices of erosion potential and particle size to each tributary reach. The indices were calculated as an average across the HUC-6 corresponding to each particular stream reach.

Stream sedimentation is often a critical factor limiting the spatial distribution of salmonid spawning. In riverine systems, certain environmental traits promote the accumulation of stream sediments that can obscure suitable substrates. Specifically, the deposition of fine particles within streams is effected by factors such as soil type and hydrological conditions. In our analysis, these attributes were employed in order to determine where sedimentation might influence salmon and steelhead production. Most crucial to our investigation were the identification of highly erodible soils and low gradient streams which maximize particle detachment and limit transport.

Two primary data sources were utilized in our effort to locate probable sedimentation: the USDA-NRCS STATSGO soil survey, and reach level gradients obtained from USGS DEMs. The STATSGO dataset contains a measure of potential erodibility, or K factor, which is a predictive measure (0.0 – 1.0) of particle detachment resulting from rainfall. Soil texture and permeability are the key factors in determining the K factor, with clays having the lowest value (least erodible) and silts having the highest (most erodible). The USDA-NRCS considers soils with a K factor greater than 0.40 to be the most highly erodible and prone to runoff. Soils in this category are predominately composed of silts and silty loams. It should be noted that K factor is a measurement for bare soil conditions, and our analysis is for intrinsic habitats. However, natural disturbances would likely aid in the process of sedimentation more readily in soil units with the greatest erosion potential.

In addition to soil erodibility, we utilized stream gradients as a measure of depositional potential. Gradients were calculated for all 200-meter reaches within our study area using the minimum and maximum elevation per reach as obtained from the USGS DEMs. Low gradient streams result in lower flows and reduced stream power, which in turn promotes depositional rather than transport processes.

In order to determine stream reaches most at risk for sedimentation, we developed a habitat screening mechanism based on K factor and gradient. We first selected low gradient streams (<= 0.5%) and then intersected these results with soil units having a K factor greater than 0.4. Also, we identified sub watersheds having at least 50% of their area within highly erodible soils (K > 0.4). Low gradient reaches within these watersheds and those intersecting highly erodible soil units were attributed with high sediment potential. Additionally, the accumulated mean K factor was calculated for upstream reaches above all 200-meter segments, and where the accumulated mean was greater than or equal to 0.4 we applied the sediment screen. In reaches that were previously classified with moderate or high IP ratings, values within the sediment screen dropped to low.

Stream Velocity

For steelhead, an additional screen was developed in order to address highly rated IP areas identified as low potential by regional biologists. These reaches were primarily at the upper ends of drainages or emanated from relatively arid headwater areas. Generally, it appeared that persistent low flow conditions would preclude steelhead occupation. Using the NHD Plus database, we spatially joined mean annual stream velocity attributes to the 200-segments within the IP analysis. We then compared existing measure of productivity at specific locations (John Day steelhead index reaches, IDFG suitability maps, and Upper Columbia redd counts) to NHD calculated mean annual velocities and determined upper and lower limits. As with the sediment screen, all moderate and high potential rated reaches were changed to low if they were located outside the acceptable value range.

John Day Gravel Assessment-- stream confinement and gradient

Additional reviews from local biologists identified highly rated IP steelhead habitat within confined reaches and higher gradients that unlikely could support suitable substrate development. Stream gravel assessments within the Joseph Creek subwatershed were used to evaluate the significance of gradient and confinement to the distribution of suitable spawning substrates. The original dataset was developed by ODFW and was based upon stream surveys conducted in 1965 and 1966.

Spawning gravel summaries were classified by ODFW using "good" and "marginal" qualifiers, but the total of both categories were used for our analyses. We summarized mean bankfull width, confinement (valley width / bankfull width), and gradient for all 200 meter reach segments within the surveyed streams and joined it to the stream gravel dataset. The confinement parameter was expressed as the percent of stream confined (confinement was defined for reaches where valley width was less than or equal to 4 times bankfull width). To facilitate the standardization of gravel quantity among streams, the gravel area was divided by the bankfull stream area to compute the amount of gravel per unit stream area. These values were then multiplied by 10,000 to convert the values to integers.

We utilized an ANOVA to determine if there were differences between the amount of available spawning gravels within different gradient and confinement groups. Percent of stream confined was classified into two categories (<10% confined [uc], >10% confined [c]), and gradient was classified into 3 groups (0 – 1.5%, 1.5 – 4.0%, and > 4.0%). From the ANOVA, the streams with a greater percentage of confinement and higher gradients were shown to contain fewer spawning gravels as a percentage of stream area. These results were applied to our IP assessment by introducing confinement parameters to the steelhead habitat criteria.

Middle Fork Salmon and Upper Columbia Redd Surveys

The Middle Fork Salmon survey included GPS located redds within all accessible streams (1995-2003 return years, R. Thurow USFS pers. comm.). In the Upper Columbia (Okanogan, Methow, and Wenatchee subbasins), GPS data was collected (2004-2006) for redds observed in specific streams (C. Baldwin, WDFW pers. comm.) By identifying the nearest IP stream reach for each redd, we successfully quantified the total number observed per 200-meter segment in the intrinsic potential dataset. These results enabled us to evaluate our classification of IP habitat using observed redd densities by spatially joining predicted values to field measurements. Categories were summed by total Chinook or steelhead redds located within each habitat class, and an ANOVA was used to compare the total redd counts to unique categories. The results showed general agreement between our IP analysis (predicted quality) and redd density (observed productivity), but some differences were noted. These results were used to adjust model parameters to reflect spawning patterns observed for stream type Chinook in the Middle

Fork Salmon River and steelhead in the Upper Columbia, and formulated our final rating scheme.

Using the results from our ANOVA analyses, the greatest mean redd count for a habitat category was assigned a “high” intrinsic spawning potential. This group represented the most preferred habitat by observed Chinook and steelhead spawners in the dataset. Any grouping whose mean redd count was at least fifty percent of this highest value was also attributed with a “high” intrinsic potential. Continuing, those categories receiving between 25% and 50% of the highest value were given a “moderate” rating, between 12.5% and 25% a “low” rating, and less than 12.5% a “negligible” rating. The “negligible” rating was only applied to the stream type Chinook IP classification. These values were then used to weight potential habitat (for both area and length) so that a “high” rated reach was multiplied by 1.0, “moderate” by 0.5, “low” by 0.25, and “negligible” by 0.0. Functionally, the “negligible” category had the same effect on total habitat as inaccessible areas or those failing to meet our minimum width criteria (which were assigned a “none” rating). Neither the “none” or “negligible” classification contributed habitat, in terms of weighted length or area, to the total intrinsic spawning potential per population.

Species Specific Ratings

The final rating assignments are provided in Tables C-1 and C-2 for yearling type Chinook salmon and steelhead reaches, respectively.

Yearling Chinook

Table C-1. Relative potential for Interior Columbia basin Spring and Spring/Summer Chinook salmon spawning and initial rearing as a function of stream reach physical characteristics. BF: Bankfull stream width; Gradient: percent change over 200 m reach; and relative ronfinement: valley width expressed as ratio to BF stream width.

Stream Width/ Gradient Categories		**Valley Width Ratio (Ratio of valley width to bankfull stream width)**		
Bankfull Width (BF)	**Gradient**	**Confined (<= 4 X BF width)**	**Moderate (4 to 20 X BF width)**	**Wide > 20 X BF width**
BF < 3.7 m	≥ 0	None	None	None
BF 3.7 to 25 m	0 - 0.5	***Medium***	***High***	***High***
	0.5 - 1.5	***Low***	***Medium***	***High***
	1.5 - 4.0	***Low***	***Low***	***Medium***
	4.0 - 7.0	Negligible	***Low***	***Low***
	> 7.0	None	None	None
BF 25 m to 50 m	0 - 0.5	None	***Medium***	***Medium***
	0.5 - 10.0	None	None	None
	≥ 10	None	None	None
BF > 50 m	≥ 0	None	None	None

Steelhead

Table C-2. Relative potential for Interior Columbia basin steelhead spawning and initial rearing as a function of stream reach physical characteristics. BF: Bankfull stream width; Gradient: percent change over 200 m reach; and relative confinement: valley width expressed as ration to BF stream width.

Stream Width/ Gradient Categories		**Valley Width Ratio (Ratio of valley width to bankfull stream width)**		
Bankfull Width (BF)	**Gradient**	**Confined** (<= 4 X BF width)	**Moderate** (4 to 20 X BF width)	**Wide** > 20 X BF width
BF < 3.8 m	≥ 0	None	None	None
BF 3.8 to 25 m	0 - 0.5	None	***Medium***	***Medium***
	0.5 - 4.0	***Low***	***High***	***High***
	4.0 - 7.0	None	***Low***	***Low***
	> 7.0	None	None	None
BF 25 m to 50 m	0 - 4.0	***Low***	***Medium***	***Medium***
	> 4.0	None	None	None
BF > 50 m	≥ 0	None	***Low***	***Low***

Population Totals: Historical Potential Spawning Habitat

An estimate of potential spawning habitat area is a particularly relevant measure for use in expressing the size of specific populations relative to abundance and productivity criteria. A strong tendency for returning spawners to home back to natal spawning areas is a general characteristic of Chinook and steelhead. The predominant life history patterns for both of these species involve a year or more freshwater rearing, generally in the natal tributary. Returns to particular spawning reaches are therefore largely dependent upon the production from the previous generation of spawning in that same reach. As a result, the availability of suitable quantities of high quality rearing habitat also affects production and therefore average abundance associated with a particular spawning area.

Once final habitat adjustments were completed for the IP analysis, we weighted stream metrics using our new screening elements. In some cases, new criteria changed the rating by one or two categories, and in others the screen factor completely eliminated habitat potential (Table C-3). We used these updated results to generate population specific estimates of total spawning potential. We expressed the total amount of historical spawning habitat for each population as an equivalent amount of good spawning habitat. We weighted the amount of habitat (length and area) in each 200 meter reach within a population by a simple proportion corresponding to the assigned reach rating – high, medium, or low (we included a fourth category – negligible, for yearling type Chinook populations). Units of habitat rated with high production potential for a species were given a weight of 1. Units of medium production potential were given a relative rating of 0.5 and habitat units classified as low production potential were assigned a relative rating of 0.25. For Chinook populations, some reaches were rated as negligible. For the purposes of this analysis those reaches were assigned a weight of 0. A relative index of productivity for aggregate areas was calculated by summing the weighted total amounts of habitat within each category within the appropriate geographic units. The ratios of 1 to .5 to .25 for high, medium and low intrinsic potential categories reflect the patterns observed in the WDG steelhead parr density study (Gibbons et al., 1985, table 6) and are generally consistent with relative densities reported for spring Chinook late fall parr in the Idaho studies.

Tributaries Supporting Two Chinook ESUs

The intrinsic potential analysis described above is based on general physical requirements for Chinook spawning and early rearing. Some population areas in the Interior Basin support more than one Chinook ESU. We adjusted the total area assigned to the listed spring Chinook population in accordance with the following observations.

Upper Columbia Spring Chinook

Each of the extant populations of upper Columbia spring Chinook is associated with a population of summer Chinook. With the possible exception of the Entiat, summer Chinook runs are believed to have been endemic to each system. Upper Columbia River summer Chinook salmon are classified in a separate ESU. There are significant differences in life history patterns between the two ESUs - summer Chinook return to the Columbia River primarily in July and August, spawn approximately 1 month later than spring Chinook, and leave their natal tributary for the mainstem during the summer of their first year of life. Summer Chinook spawn later and lower down in the mainstems of the major Upper Columbia tributaries. Gradient and substrate characteristics of stream habitat within the stream sections used for spawning are similar for both runs. There is some overlap in each system between the lower end of the spring run spawning and the upper end of summer Chinook spawning.

Summer Chinook salmon utilize the Wenatchee River mainstem up through Tumwater Canyon for spawning. Spring Chinook salmon spawning is generally confined to the major tributaries to the Wenatchee and the mainstem reach downstream of Lake Wenatchee to Tumwater Canyon.

In the Methow basin, summer Chinook spawning is confined to the mainstem Methow River below the Chewuch River confluence (Anon., 1998). Chapman et al. (1994) states that summer/fall Chinook utilize the lower 50 miles of the Methow River mainstem. In the Okanogan, summer Chinook salmon currently spawn between Zosel Dam and the town of Mallott and from Enloe Dam to Driscoll Island.

Spring Chinook spawning in the Entiat drainage occurs above river mile 16 of the mainstem and in the lower five miles of a major tributary, the Mad River. Summer Chinook spawning extends downstream from approximately river mile 20 to the mouth.

Snake River Spring/Summer Chinook

There is limited potential for overlap in spawning/rearing areas among ESUs of Chinook in the Snake Basin.

Tucannon River: Currently, fall Chinook use the lower 10 km of the Tucannon mainstem for spawning (redd survey data summarized in Milk et al, 2005). Spring Chinook spawning currently occurs in the mainstem from the mouth of Sheep Cr. (river mile 52) downstream to King Grade (RM 21) - draft Lower Snake Recovery Plan p 82). The Tucannon system has been heavily impacted by human activities, resulting in increased stream temperatures and high sedimentation rates. Projections of historical temperatures indicate almost all of the mainstem Tucannon would have had average July temperatures below 22 deg. C.

Table C-3. Population total historical intrinsic potential spawning habitat. Units are 10,000 m^2 (equivalent to 1 km of 10 wide stream of reach habitat rated in High category). Core area habitat is the portion of the total within the major tributary drainage for the corresponding population.

Steelhead

ESU	Population	Total	Core
Upper Columbia Steelhead	UCENT-s	141	136
	UCMET-s	533	526
	UCWEN-s	550	488
	UCOKA-s (US)	352	336
	UCCRC-s	360	---
Middle Columbia Steelhead	MCWSA-s	48	46
	MCKLI-s	436	435
	MCFIF-s	191	164
	DREST-s	408	408
	DRWST-s	825	457
	MCROC-s	67	67
	MCWIL-s	298	255
	DRCRO-s	1156	---
	JDLMT-s	1175	1170
	JDNFJ-s	687	687
	JDMFJ-s	296	296
	JDSFJ-s	103	103
	JDUMA-s	335	335
	MCUMA-s	907	783
	WWMAI-s	371	360
	WWTOU-s	229	229
	YRTOP-s	191	157
	YRSAT-s	411	180
	YRNAC-s	734	535
	YRUMA-s	921	921
Snake River Steelhead	SNTUC-s	272	188
	SNASO-s	157	94
	CRLMA-s	743	743
	CRNFC-s	841	---
	CRLOL-s	78	78
	CRLOC-s	340	340
	CRSEL-s	500	500
	CRSFC-s	262	262
	GRLMT-s	306	306
	GRJOS-s	194	194
	GRWAL-s	399	399
	GRUMA-s	714	714
	IRMAI-s	304	304
	SRLSR-s	276	85
	SRCHA-s	169	60
	SFSEC-s	92	92
	SFMAI-s	299	299
	SRPAN-s	163	125
	MFBIG-s	428	428
	MFUMA-s	448	448
	SRNFS-s	98	62
	SRLEM-s	426	368
	SRPAH-s	385	257
	SREFS-s	379	165
	SRUMA-s	464	464

Chinook

ESU	Population	Total	Core
Upper Columbia Spring Chinook	UCENT	30	30
	UCMET	146	146
	UCWEN	153	153
	UCOKA (US)	40	41
Snake River Spring/Summer Chinook	SNASO	20	20
	SNTUC	44	44
	GRWEN	38	38
	GRLOS	106	106
	GRLOO	8	8
	GRMIN	42	42
	GRCAT	66	34
	GRUMA	91	91
	IRMAI	48	48
	IRBSH	28	28
	SRLSR	44	28
	SFMAI	75	55
	SFSEC	47	47
	SFEFS	60	60
	SRCHA	34	21
	MFBIG	60	60
	MFLMA	18	8
	MFCAM	26	26
	MFLOO	27	27
	MFUMA	53	53
	MFSUL	12	12
	MFBEA	50	50
	MFMAR	23	23
	SRPAN	41	40
	SRNFS	19	17
	SRLEM	135	133
	SRLMA	144	144
	SRPAH	111	111
	SREFS	57	57
	SRYFS	21	21
	SRVAL	27	27
	SRUMA	69	69

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